Unielement, Oxygen-Rich Preburner

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A full-flow, staged combustion cycle using an oxygen-rich preburner has been a candidate for use on the proposed reusable launch vehicle. The oxygen-rich combustion gas used to drive the turbine system would have a high density; consequently, the required turbine power can be obtained by the low-temperature preburner products. This will improve turbopump operability and durability. However, before full-scale engine development can proceed, the issues of ignition characteristics, flame stability, temperature striation, and combustion performance in the preburner at high oxidizer-to-fuel mixture ratio must be resolved (in addition to material compatibility). MSFC and the Propulsion Engineering Research Center of Pennsylvania State University are jointly investigating advanced injection techniques for the oxygen-rich preburner.

In this effort, two types of injection techniques will be examined. The first one, direct injection, has propellants being directly introduced at the injector face of the preburner. The other technique, near-stoichiometric/dilution injection, has the fuel and some oxidizer flow through the injector face at a stoichiometric mixture ratio. The combustion hot gas is then diluted with the rest of the oxidizer downstream. The current effort emphasizes the direct injection technique using a coaxial swirl injector for the liquid oxygen and gaseous hydrogen.

The experiment was conducted with a 2- by 2-inch square combustor (fig. 46). Liquid oxygen enters into the chamber through the center injection post in a swirling motion, and gaseous hydrogen flows through the outer annulus of the injection element. The hot-fire tests were accomplished for chamber pressures from 140 to 500 pounds per square inch and a mixture ratio range of 3 to 166. (The C* efficiencies for two chamber pressures of 200 and 300 pounds per square inch are shown in fig. 47.) The results show that the efficiency is better than 92 percent for both conditions. For higher chamber pressures, the hydrogen density is proportionally increased and causes a

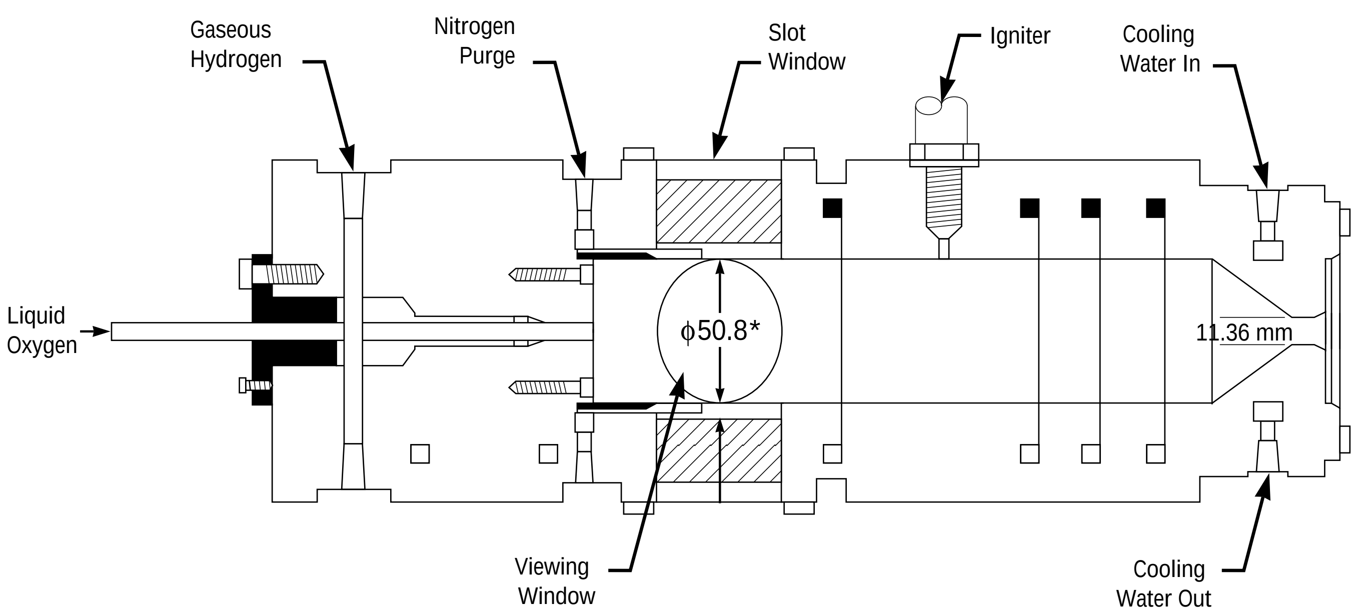

FIGURE 46.—Schematic of unielement combustor.

reduced injection velocity for a given flow rate. The associated degradation in liquid-oxygen atomization tends to reduce the combustion efficiency. Typical chamber-pressure traces of the hot-fire tests have been plotted (fig. 48), and the data indicate stable burning after the ignition period.

At present, Penn State continues testing the swirl coaxial injector to provide detailed information of the combustion behavior and flow-field characteristics. In addition, the injector for the RP–1/liquid-oxygen propellant system and the near-stoichiometric/dilution injector are being designed. MSFC is in the process of testing similar injectors at higher chamber pressures.

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University Involvement: Robert J. Santoro and Charles Merkle, Propulsion Engineering Research Center, Pennsylvania State University

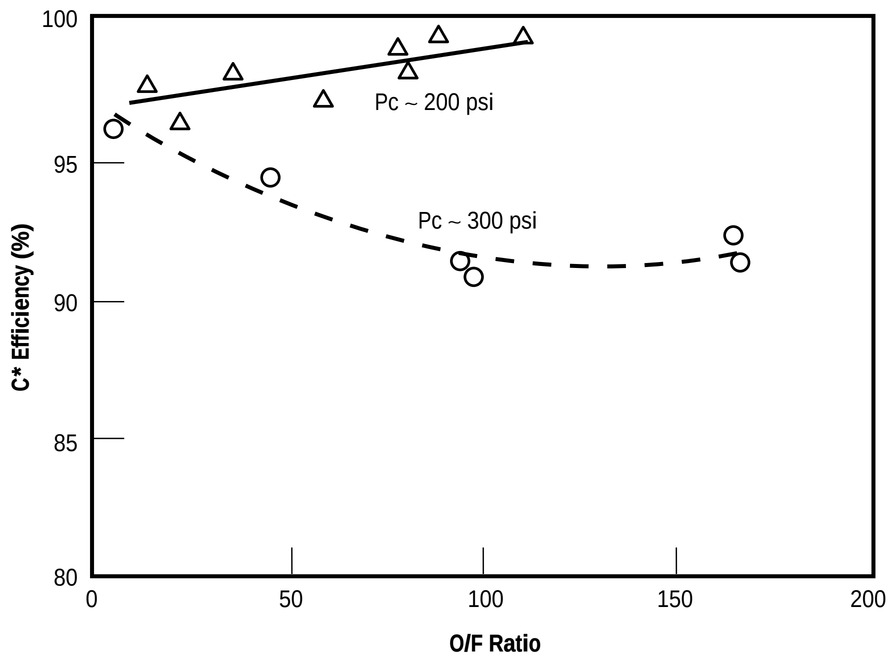

FIGURE 47.—C* efficiency at chamber pressures of 200 and 300 pounds per square inch.

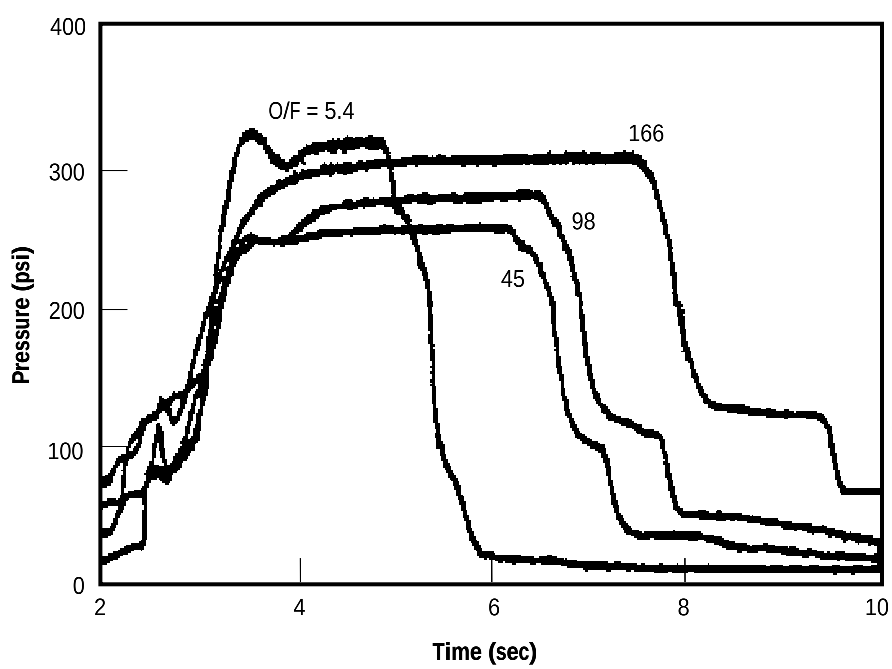

FIGURE 48.—Typical chamber-pressure traces for mixture ratio range from 5.4 to 166.